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Project Summary

In-Situ Methods to Control Emissions from Surface Impoundments and Landfills

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The full report presents the results of a two-year study which included laboratory investigations as well as a comprehensive literature review on methods of reducing the rate of emissions of volatile chemicals from surface impoundments and landfills. It presents information on the following in-situ methods which may be employed to reduce emission rates: air supported structures, floating solid objects, shape modification, aerodynamic modification, floating oil and/or surfactant covers and synthetic membranes over landfills.

Conclusions are drawn with respect to the suitability of each of the methods under various circumstances and the degree of control which might be expected.

The full report was submitted in fulfillment of Cooperative Agreement No. 810856-01-1 by the University of Arkansas under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from October 1, 1983 to September 30, 1985. The full report is under CR710856.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The full document finalizes a study involving laboratory and pilot scale investigations as well as a literature review that was conducted to evaluate *in-situ* control methods that might be readily adopted for use at existing treatment, storage, and disposal facilities (TSDF) for reducing emissions of Volatile Organic Chemicals (VOC). Emissions of VOC from TSDFs are a significant source of contaminants entering the atmosphere. It has been reported that at least one-third of the total emissions of over 50 volatile, hazardous chemicals are from TSDFs.

The main focus of federal and state regulations of TSDFs in the past has been to minimize contamination of surface and ground water, to prevent air contamination from incineration, and to prevent accidental exposure. However, more recently, attention has been directed to direct emissions from TSDFs.

Much work had been done in quantifying impoundment and landfill emissions, and simplified models of the mass-transfer processes had been developed and were shown to be generally valid. With that background, it was possible to propose methods to reduce the emissions. Some control methods simply interpose a physical barrier between the impoundment and the atmosphere, whereas others attempt to modify the mass transfer process in more subtle ways to bring about reductions.

This work was undertaken to consider all types of controls which might be added to existing facilities in order to reduce direct emissions from surface impoundments and landfills.

The methods treated in this document include: complete, positive control by use of an enclosure which precludes loss of any vapor to the air, such as a domed structure of synthetic membrane covering the entire impoundment; floating solid objects which restrict the exposed surface area of the impoundment; modification of the shape of the impoundment; aerodynamic modifications; the addition of other materials, such as oils or surfactants to the impoundment; and the use of synthetic liner type membranes over landfills.

To evaluate a control scheme and to make a choice of control method, the purpose of the impoundment and the goals of the control strategy must be considered. Frequently the reduction or elimination of emissions may only delay the process. To prevent volatile emissions entirely there must be some method of destruction of VOC, which presumes some method of capture after removal from water. If the goal is to reduce the rate of emission, thus to reduce the concentration of VOC at some receptor location, then an absolute elimination might not be necessary.

The parameters affecting the emission rate include the wind as well as the size and orientation of the surface impoundment. The mass transfer process which governs the volatilization of almost all the chemicals of interest is the liquid phase process. Since this is so, differing rates from one chemical to another are largely a matter of liquid phase diffusivity differences, and the rates do not vary greatly from one chemical to another, in the usual case, due to vapor pressure variations. The assumption in this instance is simply that the volatility is high enough so that it is not generally limiting. The temperature of the water has a marked effect upon the diffusivity; the diffusivity increases approximately as the 1.8 power of the absolute temperature. Thus, a high liquid temperature favors more rapid volatilization.

Control techniques that tend to change the gas phase resistance will be effective for only a few chemicals, those with very low Henry's law constants. Such materials will display very low vapor pressure and/or higher solubility in water.

When immiscible, volatile materials float on the surface, the emission rate will be greatly influenced by the gas phase resistance, which is normally quite low compared to the liquid phase resistance. Such instances will be characterized by extremely rapid volatilization.

If an impoundment is being used to carry out aerobic digestion, then a continual resupply of oxygen is necessary, and devices such as aerators which are intended to increase oxygen transfer will simultaneously increase the volatilization rate, whereas methods which reduce volatilization will normally reduce oxygen transfer as well.

General Conclusions

A number of options are available to reduce the rate of emissions from surface impoundments. Choosing among the options involves consideration of the goals and circumstances surrounding the application. Each of the methods considered was found to provide emission rate reductions.

In many cases it is impossible to predict the degree of control that might be expected with a high degree of accuracy. This is perhaps not very significant, because it is also impossible to predict accurately the emissions without controls.

Specific conclusions relating to the various options considered or studied in this work are given below.

Complete enclosure of an impoundment with an air supported structure will provide nearly complete control if a method of collecting the vapors such as an adsorbent trap is available.

Floating covers will restrict the surface area and thereby reduce emissions accordingly. These include rafts, synthetic membranes and hollow, interlocking spheres. Control of 90% or more would be possible.

The shape of an impoundment and its orientation with respect to the wind will influence the emission rate. Reducing the fetch (down-wind distance) will reduce the emission rate as will increasing the depth.

Wind fences were found to be surprisingly effective in reducing the emission rate in a laboratory simulator. Reductions as high as 80% appear to be possible.

Laboratory simulations showed floating oil layers to be effective in reducing emissions. In the absence of wind, reductions of over 90% were achieved. Although wind tends to blow the oil cover to one side, it may still be effective.

Laboratory measurements of permeability of a polyvinylchloride membrane indicated that such a membrane would not provide significant protection against vapor flow out of a landfill.

Study Results

Complete Enclosure by Air Supported Structures

Complete enclosure of a surface impoundment by an air-supported structure is a feasible control method if a suitable method is available either to collect or dispose of generated vapors. This is the only feasible method if a surface aerator were to be used to improve oxygen transfer. Air supported structures are susceptible to wind damage as well as weathering. Some vapors may be harmful to the polymeric materials. The control effectiveness can approach 100%.

Vapors could be collected by controlled venting into an adsorption trap, or perhaps directly into an incinerator. The vent gases will be nearly saturated with water vapor which can interfere with adsorption.

Floating Solid Objects

Floating solid objects include synthetic membrane covers, rafts, and hollow plastic spheres.

Floating synthetic membrane covers have been used successfully and are feasible if oxygen transfer is unnecessary and if outgassing of the impoundment contents is not expected. Some liner material may be highly permeable to some organic vapors. The floating membrane is subject to damage by weathering and may also be damaged by contact with the waste. The control effectiveness can approach 100%.

Rafts and other such structures restrict the surface area of an impoundment which is exposed to the air and reduce emissions and oxygen transfer accordingly. Rafts generally have a short lifetime because they are damaged by contact with the waste water. The maximum control effectiveness of rafts is about 90%.

Floating hollow spheres have been shown to reduce emissions by as much as 80 to 90%. The most popular spheres are made of polypropylene and have projections to prevent rotation in the wind. The spheres restrict oxygen absorption to the same degree that they reduce emissions; they may be blown away in a high wind.

Shape Modification of Surface Impoundments

Shape modification is meant to include berm height, liquid depth, length or width of the impoundment and directional orientation.

Increasing berm height is an effective method of emission reduction, although its effectiveness cannot be accurately predicted. This method is effective in reducing wind-enhanced emissions, with emissions being approximately inversely proportional to the square root of the berm height.

For a given impoundment volume, increasing impoundment water depth will cause emission reduction by reducing the surface area. Wind-enhanced mass transfer coefficients may also be reduced at the same time if the actual water depth is increased.

Wind-enhanced emissions can be reduced if the fetch is reduced. Relatively narrow impoundments will have lower emissions if the wind is blowing normal to the longer dimension of the impoundment.

Aerodynamic Modification

Laboratory investigations of wind barriers show them to be quite effective in reducing emissions under wind-enhanced conditions. The performance of perimeter and network fences were found to be generally similar. The mass-transfer coefficient was found to be approximately proportional to the square root of the fetch to height ratio, up to a maximum of 160. A commercial, porous wind fence material commonly used for dust control was found to be much superior to solid fence material. Wind fences can potentially achieve emission reduction of up to 80%. Oxygen absorption will be affected similarly (Table 1).

Floating Oil Layers

A layer of immiscible liquid floating on the surface of an impoundment was found to be quite effective in reducing emissions. Under conditions of little wind, volatile materials with low solubility in the oil cover material were controlled more effectively than those which are more soluble. However, an oil covering of about one cm depth would provide at least 90% emission reduction for any volatile.

In the presence of wind, the covering may be blown aside. Under windy conditions, the effect of solubility is variable; with low winds, a low solubility in the oil is preferable, but with higher winds a high solubility is preferable. The mixing action of higher winds tends to cause the volatile solute to transfer to the oil phase, where emission mass transfer coefficients are markedly lower. For the windy conditions, emission reduction is greater than a simple ratio of exposed to covered area would predict. Emission reduction of 50 to 80% may be expected for windy conditions, depending upon the amount of oil used.

Oxygen absorption will be reduced in accordance with the fraction of the surface that remains covered by the oil layer.

Results of pilot-scale measurements of the effectiveness of oil layers are shown in Table 2 for no-wind conditions.

Synthetic Liner Covers for Landfills

Laboratory measurements of the vapor phase permeability of a 20-mil polyvinylchloride (PVC) membrane showed a high permeability for a number of volatile organic vapors as presented in Table 3.

The performance of a membrane as a vapor barrier cannot generally be predicted and may be disappointing. Typical results of this work showed the PVC

Table 3. *Apparent Diffusivities of Several Chemical Vapors in a 20-mil Sample of Polyvinylchloride Film*

Chemical	Diffusivity (at 30°C) (cm^2/s)
Methanol	2.68 E-5
Chloroform	1.4 E-4
Dichloromethane	2.37 E-4
Bromoform	3.35 E-4
Carbon tetrachloride	1.69 E-5
Benzene	2.53 E-4
Chlorobenzene	5.03 E-4
o-Dichlorobenzene	4.96 E-4
Toluene	4.12 E-4
m-Xylene	4.73 E-4
Acetone	2.17 E-4
Diethyl Ether	1.79 E-4
Octane	7.05 E-5
Dodecane	1.06 E-3
Cyclohexane	2.18 E-5
n-Hexane	1.48 E-5
n-Pentane	2.02 E-5

Table 1. *Fence Control Simulation Results at V = 3.9 m/s and V = 2.9 m/s*
Results: Corrected to 293K

V (10 cm) = 3.9 m/s	Fence height (cm)	K_1 (cm/hr)	Reduction (%)
No Fence	0.0	3.424	0.0
Perimeter Fence			
Solid:			
90 deg.	1.7	2.750	19.7
	3.2	2.642	22.8
	6.4	2.251	34.3
80 deg.	6.4	2.087	39.1
45 deg.	6.4	3.211	6.2
Porous:			
90 deg.	6.4	0.7445	78.3
Solid Fence Networks			
5 h	1.7	0.7328	78.6
10 h	1.7	0.7540	78.0
V (10 cm) = 2.9 m/s			
No Fence	0.0	2.375	0.0
Perimeter Fence			
Solid:			
90 deg.	1.7	1.403	40.9
	3.2	1.893	20.3

Table 2. *Fractional Reduction in Emissions Using Various Mineral Oil Layer Thicknesses*

Oil Thickness (cm)	Temp. Ranges, °K		Fractional Reduction		
	Air	Water	Benzene	Acetone	n-Propanol
0.20	303-309	320-318	0	0.35	0.38
0.27	300-306	321-318	0.10	0.43	0.60
0.30	303-304	319-317	0.32	0.70	0.58
0.46	303-304	319-317	0.53	0.68	0.69

membrane to be the equivalent of only a few inches of porous soil covering.

Little data on the permeability of various polymers to vapors are available in the public domain. However, simple laboratory tests are available to measure the permeability of specific membrane materials to specific vapors.

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The complete report, entitled "In-Situ Methods to Control Emissions from Surface Impoundments and Landfills," (Order No. PB 86-121 365/AS; Cost: $11.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
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